REPORT

Willis Bond Ltd

Site 10, Wellington Waterfront
Geotechnical Concept Design

Report prepared for:

Willis Bond Ltd

Report prepared by:

Tonkin & Taylor Ltd

Distribution:

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February 2014

T&T Ref: 85778 / Rev. 0

Table of contents

1 Introduction

Willis Bond Ltd (WBL) proposes to develop Site 10, which is north of the Meridian Energy Building. WBL has engaged Tonkin & Taylor Ltd (T&T) to undertake geotechnical concept design for the proposed development.

In conjunction with Dunning Thornton Consultants Ltd (DTC) T&T has:

- Identified potential foundation options.
- Evaluated the relative merits of these options.
- Evaluated identified risks associated with the current preferred option.

The work has been carried out in accordance with our proposal of 15 January 2014.

2 Scope of work

We have undertaken the following scope of work:

- Discussed constructability and cost of deep soil mixing (DSM) with a contractor.
- Initial calculations to test feasibility and relative cost of the three options identified to date.
- Met with DTC to evaluate further the available options and identify one option (DSM) for further consideration.
- Prepared hand sketches for three considered options.
- Assessed impact of ground contamination on construction cost.
- Assessed resource consent requirements with respect to ground contamination.
- Identified geotechnical and contamination risks to the project.
- Presented the main conclusions in this report to allow WBL to evaluate the cost of the overall project.

3 Soil profile

The site's inferred soil/rock profile is summarised in Table 1 and on Sketches 2, 4 and 6 in Appendix A. This profile is based on our general knowledge of the geology and reclamation constructional the area. We are not aware of any historic ground investigations by others on the site.

Table 1. Inferred soil / rock profile

Geological Unit	Typical description	Depth to top of layer (m)	Layer thickness (m)	Typical SPT N (blows/300mm)
Reclamation Fill	Loose SILT/SAND/GRAVEL	0	5 to 6	2 to 10
Beach Sand	Loose SAND	5 to 7	1 - varies	2 to 10
Upper Alluvium	Interbedded: - Stiff SILT/CLAY. - Very dense silty SAND and GRAVEL.	6 to 8	9 to 14	 10 to 35 35 to 50
Lower Alluvium	Very dense slightly silty SAND and GRAVEL with possible occasional weaker silt beds.	15 to 20	> 50	50+
Basement Rock	Greywacke	Expected to be 80 to 120	-	-

4 Seismic subsoil class

Available geotechnical information indicates a depth to rock of 80m to 120m. With reference to NZS1170.5 Section 3.1.3.5(c) this depth to rock and overlying profile indicates the site to be subsoil class D.

5 Geotechnical issues

Geotechnical issues identified and to be allowed for in foundation design include:

- Reclamation liquefaction. Trigger 50-100 year event.
- Displacement/failure of seawall. Trigger 50-100 year event.
- Lateral spread could be >1m at southern side of site in events >100 year return period.
- Large structural compression and tension loads to be resisted. Up to 10.5MN compression and 5.5MN tension per column.
- Large lateral loads from lateral spread and building base shear to be resisted.
- Temporary support and dewatering of basement excavation. Permeable ground and inflow of ground water to excavation.
- Potential for locally weak or liquefiable soils in the upper portion of the alluvium (Upper Alluvium).
- Existing reclamation fill with a potential for ground contamination.

6 Options identified

The following foundation options have been identified for the new development:

Table 2. Options identified

Option ID	Description	Previous Applications of this Concept
1	Deep Soil Mixing (DSM) Refer Sketches 1 and 2 in Appendix A A 5.2m x 5.2m grid of 1m wide in-ground walls to 7.5m depth created by secant construction of DSM columns i.e. mixing and jetting grout into site soils. Concrete raft foundation over the grid of in ground walls. Anchor piles at selected locations. Strong/stiff in-ground walls to: - resist cyclic strains mitigating liquefaction between walls; - resist lateral spread; - transfer foundation loads to dense alluvium at depth. Anchor piles to resist high uplift loads. Perimeter in-ground walls to provide water cut off and temporary lateral restraint to basement excavation.	Proposed to repair Christchurch Town Hall. Used in: - St Georges Hospital Christchurch; - Judea pipeline Tauranga; - Chapel Street pump station foundation Tauranga; - Lincoln Road Henderson bridge foundations.
2	Gravel Columns and Piles Refer Sketches 3 and 4 in Appendix A A 2.5m triangular grid of 1m diameter in-ground gravel columns to 7.5m depth. 0.7m diameter bored belled piles to 20m depth at column locations and 1.2m diameter piles at selected locations. 8m long temporary sheet pile wall at the perimeter of the excavation. Gravel columns to mitigate liquefaction and resist lateral spread. Bored piles to provide the vertical support to the building, resist temporary earthquake loads and lateral spread. Perimeter sheet pile walls to provide water cut off and temporary lateral restraint for basement excavation.	Westpac Trust Stadium New BNZ (CentrePort)
3	Piles [1] Refer Sketches 5 and 6 in Appendix A 0.9m diameter bored belled pile to 20m depth at column locations and 1.5m diameter piles at selected locations. 8m long temporary sheet pile wall at the perimeter of the excavation. Piles alone to support the building, resist lateral spread loads and base heave on the basement in the event of liquefaction. Perimeter sheet pile walls to provide water cut off and temporary lateral restraint to basement excavation.	Market Lane

Note:

1. Initial calculations indicate that these piles may provide inadequate lateral restraint. If this option is to be considered further, specific analysis would be required to determine the pile size required and to confirm feasibility.

7 Relative merits of options

In conjunction with DTC, relative advantages and disadvantages have been discussed for the three identified foundation options. The following ranking has been applied:

Relative ranking of options	1 expected to be best
	2 -
	3 expected to be worst

Table 3. Relative merits of options

Feature	Option 1 (DSM)	Option 2 (Gravel Column and Piles)	Option 3 (Piles)
Proven design and construction in Wellington	3	1	1
Ability to resist severe earthquake without significant damage. (Ductile strain of piles could lead to some post event durability issues).	1 [a]	2	3
Number of sub-grade activities required (DSM, sheet piles, gravel columns, piles). Complexity of construction.	1	3	2
Relative construction cost (Refer Section 8)	2 [b] ($2.6 million)	2 [b] ($3.0 million)	2 [b] ($3.3 million)

Note:

a. To be confirmed by further assessment during design process

b. The limited level of accuracy of the current cost estimates does not allow the identified options to be differentiated.

8 Cost estimates

Hiway Stabilizers provided a cost estimate for Option 1 based on Sketches 1 and 2 (refer Attachment A). T&T developed relative rough order of costs for Options 2 and 3 to allow some comparison with Option 1 as summarised in Table 4.

Table 4. Cost estimate

Option	Relative cost estimate	Basis of estimate	Comments
1. DSM	$2.6 million	Estimate provided by Hiway Stabilizers based on Sketches 1 and 2 (Refer email, Appendix B).	WBL could consider obtaining a comparable estimate from other contractors.
2. Gravel Columns / Pile	$3.0 million	An initial estimate to provide comparison with Option 1 (refer Sketches 3 and 4). Low level of confidence. T&T have limited costing data available to verify this estimate.	Cost estimate not to be relied on. Recommend WBL obtain an estimate from contractors.
3. Pile	$3.3 million	An initial estimate to provide comparison with Option 1 (refer Sketches 5 and 6). Low level of confidence. T&T have limited costing data available to verify this estimate.	Cost estimate not to be relied on. Recommend WBL obtain an estimate from contractors.

Note:

Incl: Ground works as described in Sketches 1 and 6 i.e. ground improvement, bored piles and sheet pile walls.

Excl: Engineering fees; design; concrete raft and other works above the improved ground / piles; pumping of water and excavation; management of ground contamination; preliminary and general, and contingency.

9 Option evaluation

Initial option evaluation was undertaken in conjunction with DTC. During this evaluation, some potential performance and construction benefits of Option 1 were identified.

DTC / T&T propose Option 1 be considered further.

If cost estimate is to be developed based on this option, we recommend contingencies be allowed for:

- Identified risks (refer Section 9).
- Possible change to Option 2 or 3 if design issues develop.

10 Ground contamination

Based on our experience, it is likely that the fill used to form the reclamation is contaminated. Historical activities at the site may also have caused contamination. The presence of ground contamination may have the following implications:

- Additional health and safety requirements during the works.
- Special management for soil reused on site (e.g., placement under paving or clean fill cover).
- Landfill disposal of surplus soil that has to be disposed off-site (i.e., not clean fill). Pre-treatment would be required if highly contaminated material is present. The HSM method may eliminate the need for further pre-treatment.
- Odour management during works and to prevent odour entering buildings.
- Resource consent for works on a contaminated site from Wellington City Council.
- A Contamination Site Management Plan before works begin and a Site Validation Report on completion of works.
- A Long Term Site Management Plan if contamination remains onsite (e.g., beneath building or paving).

Investigations of the soil to be disturbed, including the reclamation fill and other activities that may have caused contamination, would be required to reduce uncertainty.

11 Groundwater management

Discharge of groundwater (e.g., from dewatering) to the stormwater or sewer network would require a permit from Wellington City Council.

Discharge of groundwater to the stormwater system would also require resource consent from Greater Wellington Regional Council. Resource consent may also be required for the water take, depending on the volume and rate of groundwater extracted.

12 Risk evaluation

Risk evaluation has been undertaken for Option 1 only (refer Table 5). This geotechnical and contamination risk register should be reviewed as the project progresses. Further risks are likely to be identified.

Table 5. Geotechnical and contamination risk evaluation

Item	Description	Risk Rating	Possible mitigation
1	Effectiveness of grouting of site soils.	Moderate	Trial grouting of site soils during investigations. Review of soil samples / description / lab tests by contractors. Use of additional cement. Use wider in-ground beams.
2	Ability of DSM to resist high compression loads.	High - Moderate	Use locally wider in-ground walls. Use of additional cement.
3	Bearing capacity of DSM in alluvium: Weak or liquefiable soils in upper alluvium.	High - Moderate	Borehole investigation. Deeper DSM.
4	Bending capacity of perimeter walls to resist soil pressure during construction.	Moderate	Use wider in-ground wall or additional UC steel columns.
5	Lateral deformation of seaward edge of foundation system in event of seismic failure of seawall and liquefaction.	High - Moderate	To be considered in analysis. Extend DSM ground improvement seaward of that currently allowed.
6	Groundwater inflow rates during construction.	Moderate	Modelling to estimate expected inflows. Use bentonite and / or more cement in DSM.
7	Ground contamination – disposal costs for surplus soil, resource consent requirements.	Moderate	Test soils to be excavated or disturbed. Retain contaminated soil on site where possible.
8	Groundwater requiring disposal during dewatering is contaminated.	Moderate	Test groundwater, early consideration of management options.
9	Settlement of adjoining land due to excavation / dewatering.	Moderate - Low	As Item 6. Recharge wells.
10	Underground services.	High - Moderate	Underground services check. Reroute of underground services.
11	Historic foundations / obstructions in ground.	High	Desktop Study including Historic Places Trust checks. Removal of foundations / obstructions or grout around them.
12	Bored anchor pile construction.	Moderate	Refer Market Lane and Clyde Quay Wharf.

13 Applicability

This report has been prepared for the benefit of Willis Bond Ltd with respect to the particular brief given to us and it may not be relied upon in other contexts or for any other purpose without our prior review and agreement.

Tonkin & Taylor Ltd

Environmental and Engineering Consultants

Report prepared by:	Authorised for Tonkin & Taylor Ltd by:
....	....
Emilia Belczyk	Penny Kneebone
Geotechnical Engineer	Project Director

Technical Review: Stuart Palmer (Senior Geotechnical Engineer)

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Appendix A: Concept Design Sketches

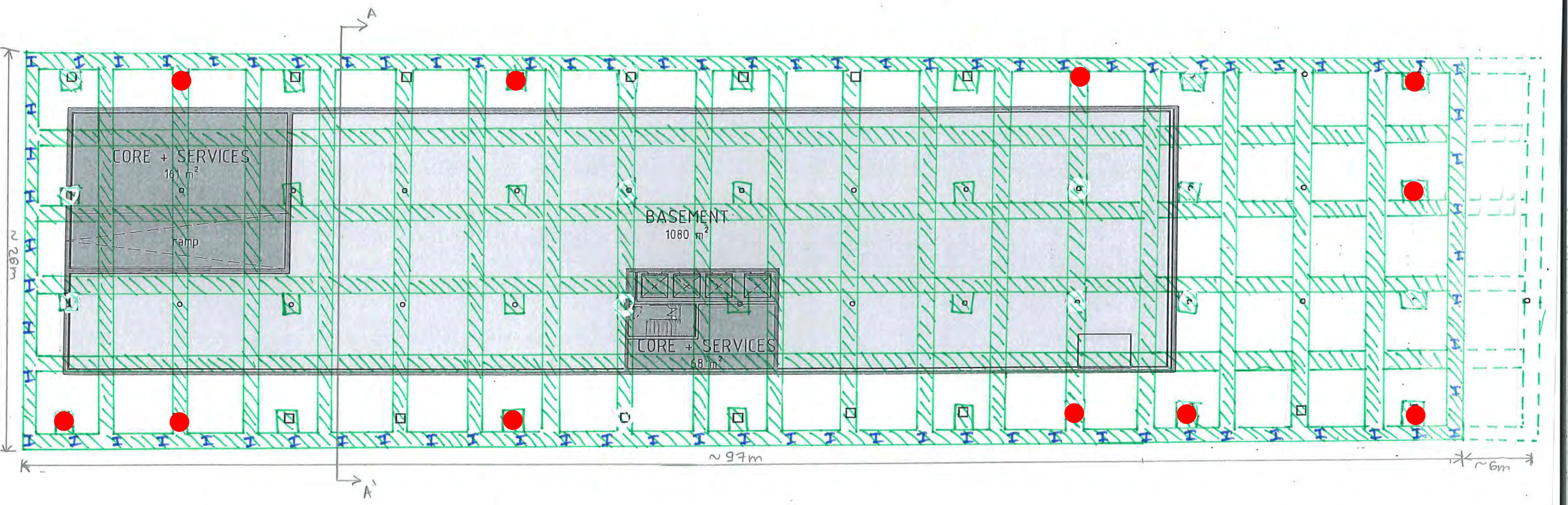
- **Sketches 1 and 2: Option 1**
- **Sketches 3 and 4: Option 2**
- **Sketches 5 and 6: Option 3**

Key:

Deep Soil Mixing (DSM), 1m diameter secant columns, approximately 7.5m deep. Limited cement mixing in the first 3.5m depth.

UC columns in every 3rd DSM column.

Tension only bored belled piles, shaft diameter 1.2m, bell diameter 2.0m. Length below raft foundations approximately 18m.



Approx. Scala 1:250

0 2 4 6 8 10m

Structural support

Option	Method used	Shaft diameter (m)	Bell diameter (m)	Length beneath raft foundation	Assumed range of loads (kN)	No of piles	Indicative cost per pile	Indicative cost per site	Total
1	Bored pile	1.2	2.0	18	Q+Qu+Et = -5500	11	$53,000	$580,000	$580,000

Ground improvement

Option	Method used	Secant piles diameter (m)	DMS length (m)	Volume of DSM (m^3)	$/m3 of DSM	Cost per site	Total
1	DSM	1.0	4.5	4608	$440.00	$2,000,000	$2,000,000

Cut off wall

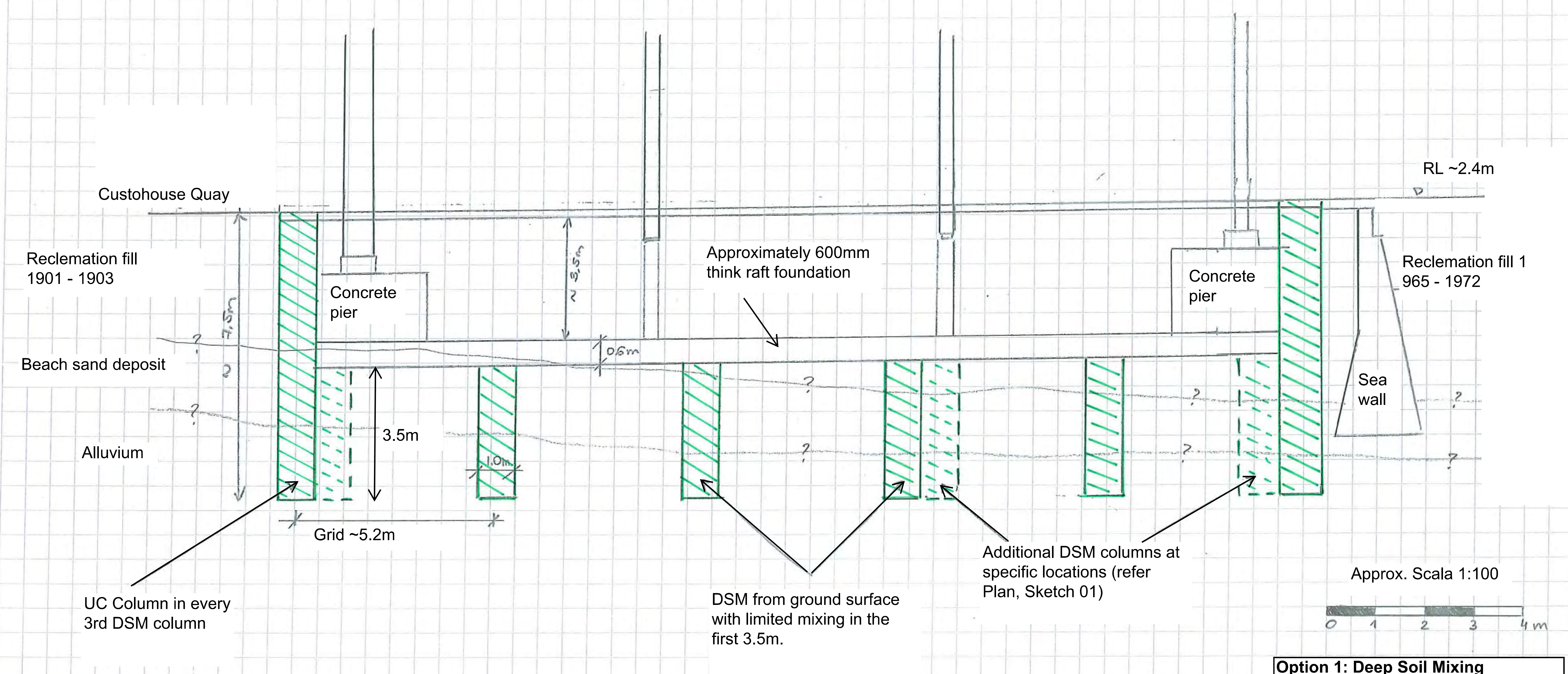
Option	Method used	Type	Pile length (m)	Approximate perimeter (m)	Cost per site	Total
1	DSM	1m dia secant piles plus UC column	7.5		cost included in ground improvement	$0

Grand Total	$2,600,000

Cost estimates are provided for comparison purposes only. The cost estimates are relative between options and not absolute. These relative costs could have an order of accuracy of ± 20% i.e. if the difference in relative cost between two options is less than say 30% then the actual cost of these two options could be the same. The cost estimates do not represent total cost of ground works and are not to be applied for project planning or any other purpose.

Option 1: Deep Soil Mixing

Plan
Sketch SK 85778-01A
T&T Job name: Site 10
T&T Job No.: 85778
Drawn: EVV 31.01.2014
Checked:



Note: Tension belled piles are not shown on this cross section Rrefer Sketch 02A)

Option 1: Deep Soil Mixing

Cross Section A-A'
Sketch SK 85778-02A
T&T Job name: Site 10
T&T Job No.: 85778
Drawn: EVV 31.01.2014
Checked:

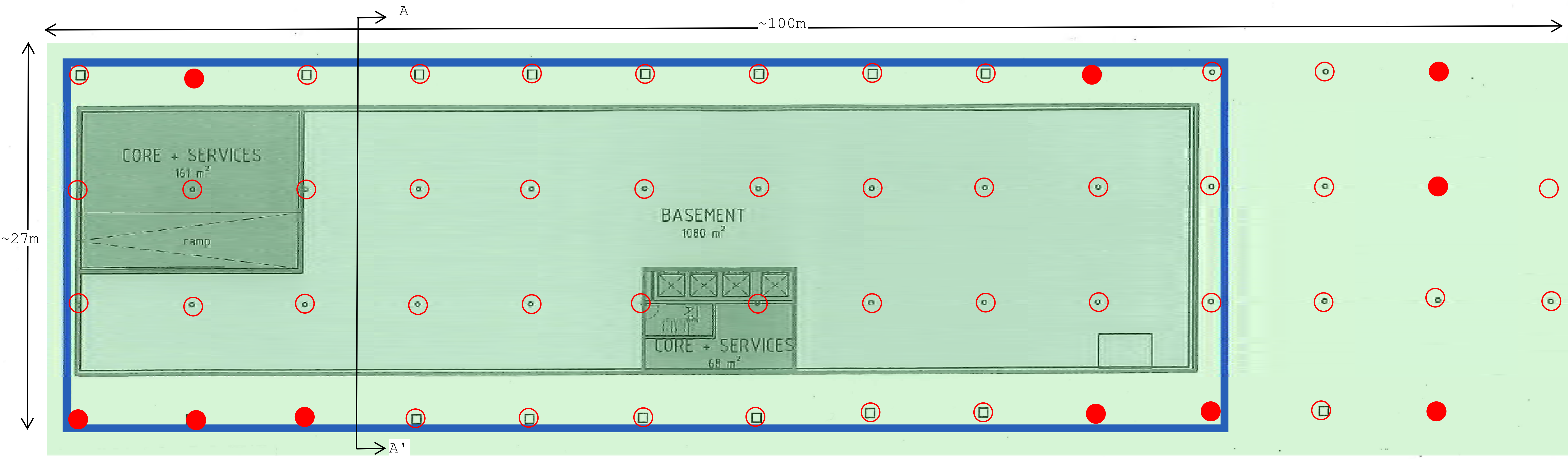
Key:

Extent of gravel columns ground improvement.

Temporary sheet pile wall, assumed L703 8m long.

Belled piles, shaft diameter 0.75m, bell diameter 1.3m. Length below raft foundations approximately 26m.

Belled piles, shaft diameter 1.2m, bell diameter 2.0m. Length below raft foundations approximately 26m.



Structural support

Option	Method used	Shaft diameter (m)	Bell diameter (m)	Length beneath raft foundation	Assumed range of loads (kN)	No of piles	Indicative cost per pile	Indicative cost per site	Total
2	Bored pile	0.75	1.3	26	1.35G = 4050 1.2G+1.5Q = 4500 G+Q = 3600	43	$28,000	$1,180,000	$1,960,000
	Bored pile	1.2	2.0	26	Q+Qu+Ec = 10430 Q+Qu+Et = -5500	11	$71,000	$780,000	

Approx. Scala 1:250

0 2 4 6 8 10 m

Ground improvement

Option	Method used	Columns diamater (m)	pile length beneath raft foundation (m)	Area of improvement (m^2)	\$/m^3 of improved ground	Cost per site	Total
2	Gravel column	1.0	4.0	2700	$40.00	$432,000	$432,000

Cut off wall

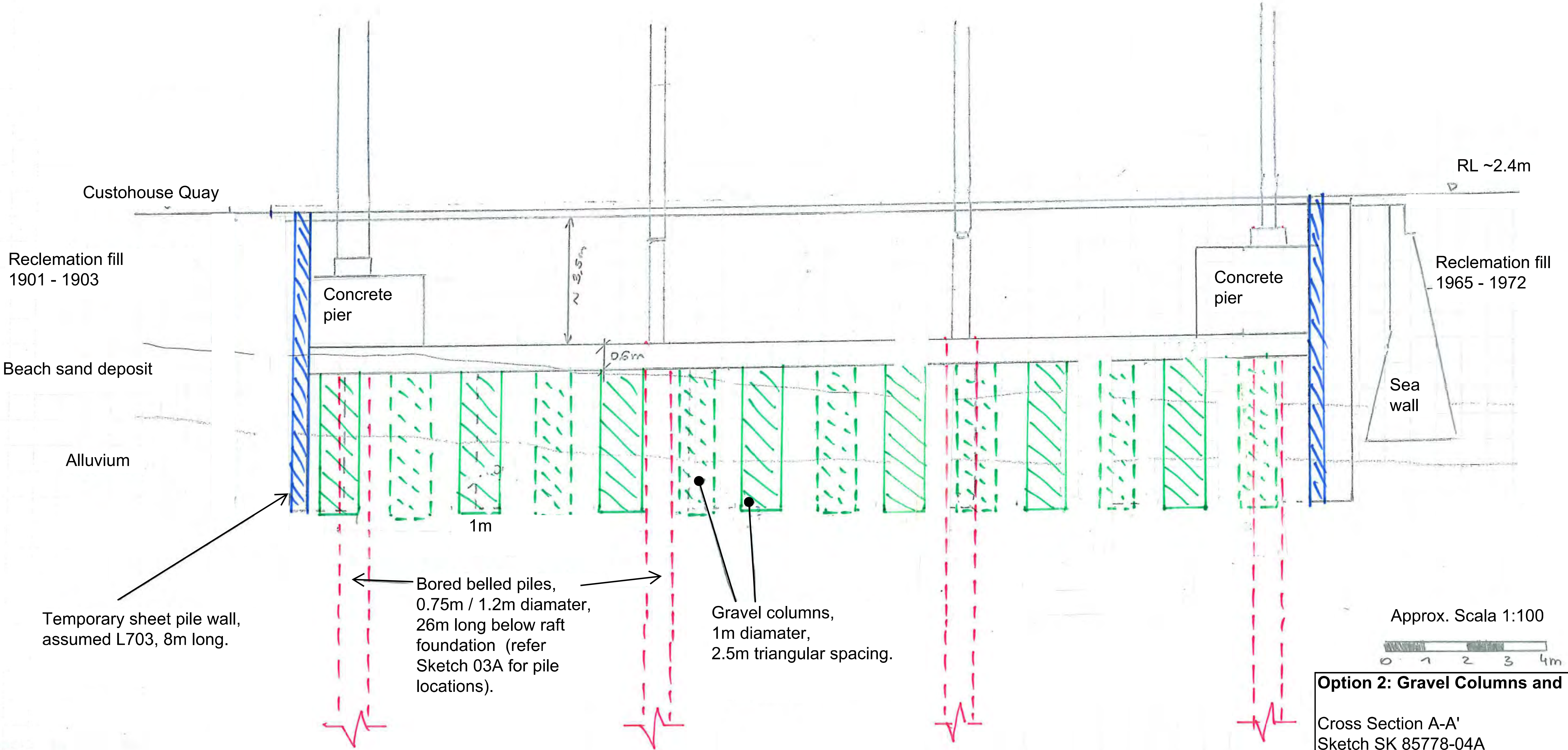
Option	Method used	Type	Pile length (m)	Approximate perimeter (m)	Cost per m^2	Total
2	Sheet pile wall	L703	8	210.00	$315	$530,000

Cost estimates are provided for comparison purposes only. The cost estimates are relative between options and not absolute. These relative costs could have an order of accuracy of ± 20% i.e. if the difference in relative cost between two options is less than say 30% then the actual cost of these two options could be the same. The cost estimates do not represent total cost of ground works and are not to be applied for project planning or any other purpose.

Grand Total $3,000,000

Option 2: Gravel Columns and Piles

Plan
Sketch SK 85778-03A
T&T Job name: Site 10
T&T Job No.: 85778
Drawn: EVV 31.01.2014
Checked:



Option 2: Gravel Columns and Piles

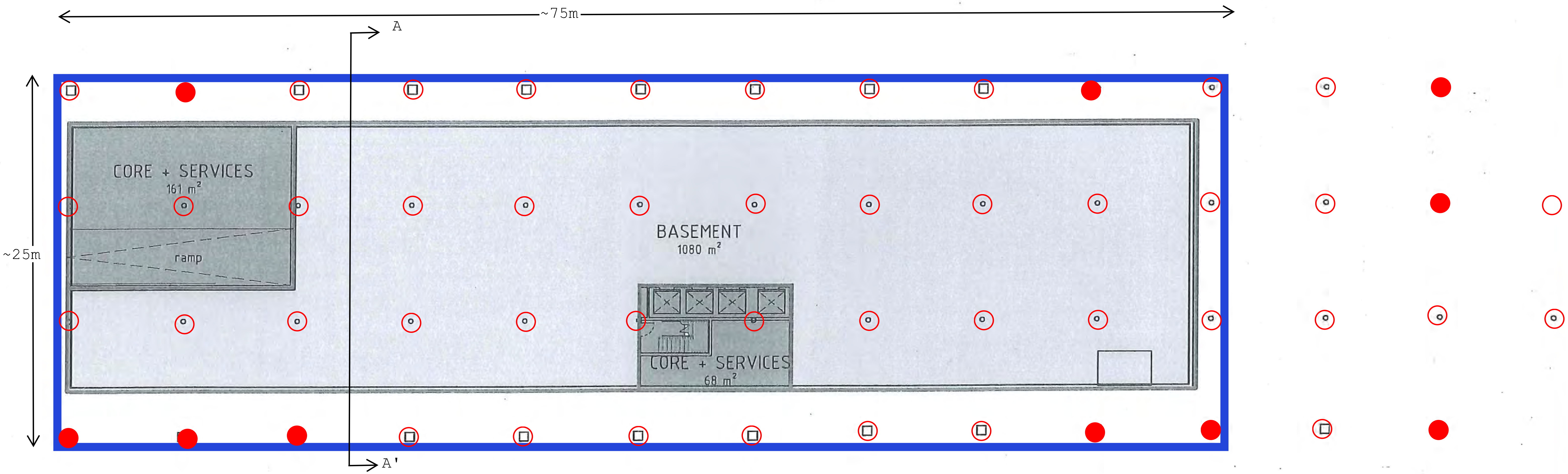
Cross Section A-A'
Sketch SK 85778-04A
T&T Job name: Site 10
T&T Job No.: 85778
Drown: EVV 31.01.2014
Checked:

Key:

Temporary sheet pile wall, assumed L703 8m long.

Belled piles, shaft diameter 0.9m, bell diameter 1.3m. Length below raft foundations approximately 24m.

Belled piles, shaft diameter 1.5m, bell diameter 2.0m. Length below raft foundations approximately 24m.



Structural support

Option	Method used	Shaft diameter (m)	Bell diameter (m)	Length beneath raft foundation	Assumed range of loads (kN)	No of piles	Indicative cost per pile	Indicative cost per site	Total
3	Bored pile	0.9	1.3	24	1.35G = 4050 1.2G+1.5Q = 4500 G+Q = 3600	43	$37,000	$1,590,000	$2,720,000
	Bored pile	1.5	2.0	24	Q+Qu+Ec = 10430 Q+Qu+Et = -5500	11	$103,000	$1,130,000	

Ground improvement

Option	Method used	Columns diamater (m)	pile length beneath raft foundation (m)	Area of improvement (m^2)	\$/m3 of concrete	Cost per site	Total
3	none						$0

Cut off wall

Option	Method used	Type	Pile length (m)	Approximate perimeter (m)	Cost per m^2	Total
3	Sheet pile wall	L703	8	210.00	$315	$530,000

Cost estimates are provided for comparison purposes only. The cost estimates are relative between options and not absolute. These relative costs could have an order of accuracy of ± 20% i.e. if the difference in relative cost between two options is less than say 30% then the actual cost of these two options could be the same. The cost estimates do not represent total cost of ground works and are not to be applied for project planning or any other purpose.

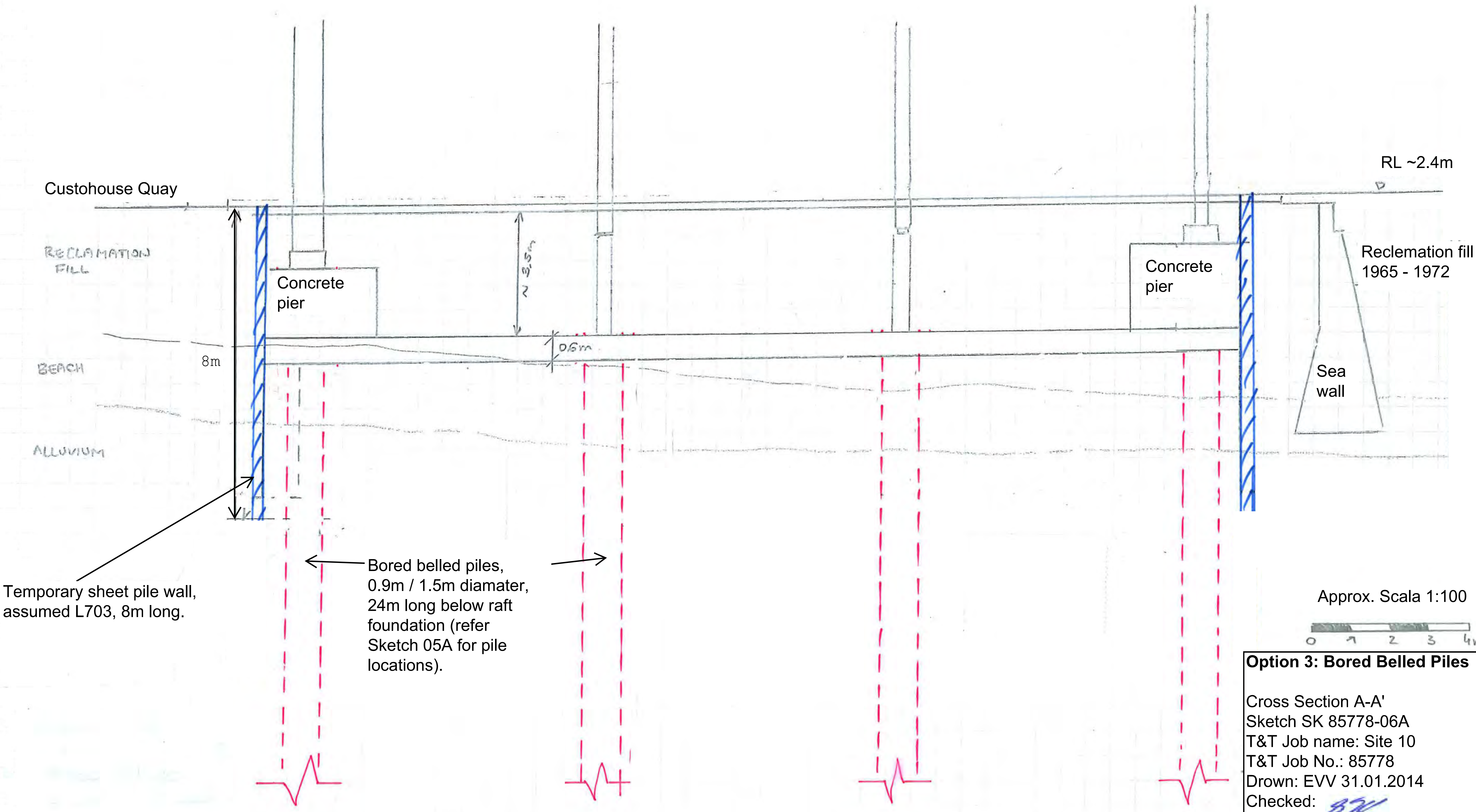
Grand Total	$3,300,000

Approx. Scala 1:250

0 2 4 6 8 10 m

Option 2: Bored Belled Piles

Plan
Sketch SK 85778-05A
T&T Job name: Site 10
T&T Job No.: 85778
Drawn: EVV 31.01.2014
Checked:



Option 3: Bored Belled Piles

Cross Section A-A'
Sketch SK 85778-06A
T&T Job name: Site 10
T&T Job No.: 85778
Drawn: EVV 31.01.2014
Checked:

Appendix B: Communication with Hiway Stabilizers

Emilia Belczyk

From: Graeme Quickfall <Graeme@hiways.co.nz>
Sent: Tuesday, 4 February 2014 3:21 p.m.
To: Emilia Belczyk
Cc: Stuart Palmer
Subject: RE: Ground improvement for Site 10 at Wellington Waterfront

Hi Emilia and Stuart

Thanks for the additional information.
Based on the concept layout plan and the information provided Im happy to provide an indicative cost estimate for the proposed ground improvement.

The price is based on 1 metre secant turbojet columns to a depth of 7.5 metres below existing ground level.

The perimeter secant wall is constructed with 1 metre diameter columns at 800 mm centres. A more detailed design review would be required to
Confirm the perimeter wall embedment depth and the design factor of safety for the retaining wall during basement excavation.
The price provided allows for 150 UCs to be installed into every third DSM column to the full 7.5 m depth.

Ive allowed for contiguous walls of 1 metre diameter columns for the internal walls.

Based on the ground conditions the columns are likely to have a 28 day UCS strength in the order of 1 – 2 MPa

We would propose to construct the columns from existing ground level and that the columns would be cut and excavated to the correct level
during the basement excavation.

We are currently completing a similar DSM foundation project on a hospital site in Christchurch and have successfully completed 10 similar
building foundation projects throughout Christchurch and NZ.

Based on the above, the cost estimate to undertake this work would be in the order of $ 1.8 to $ 2 million Plus GST.
This includes mobilisation, installation of DSM columns as described, installation of 150 UC columns as per the sketch, undertake QA testing and
reporting to verify column strength, depth and integrity. The estimate excludes and P & G items, excavation of site works, spoil removal, traffic control,
insurances, bond etc.

We would be happy to provide input into the proposed site investigations and to offer any technical advice or design input for this option.

I look forward to your feedback.

Regards

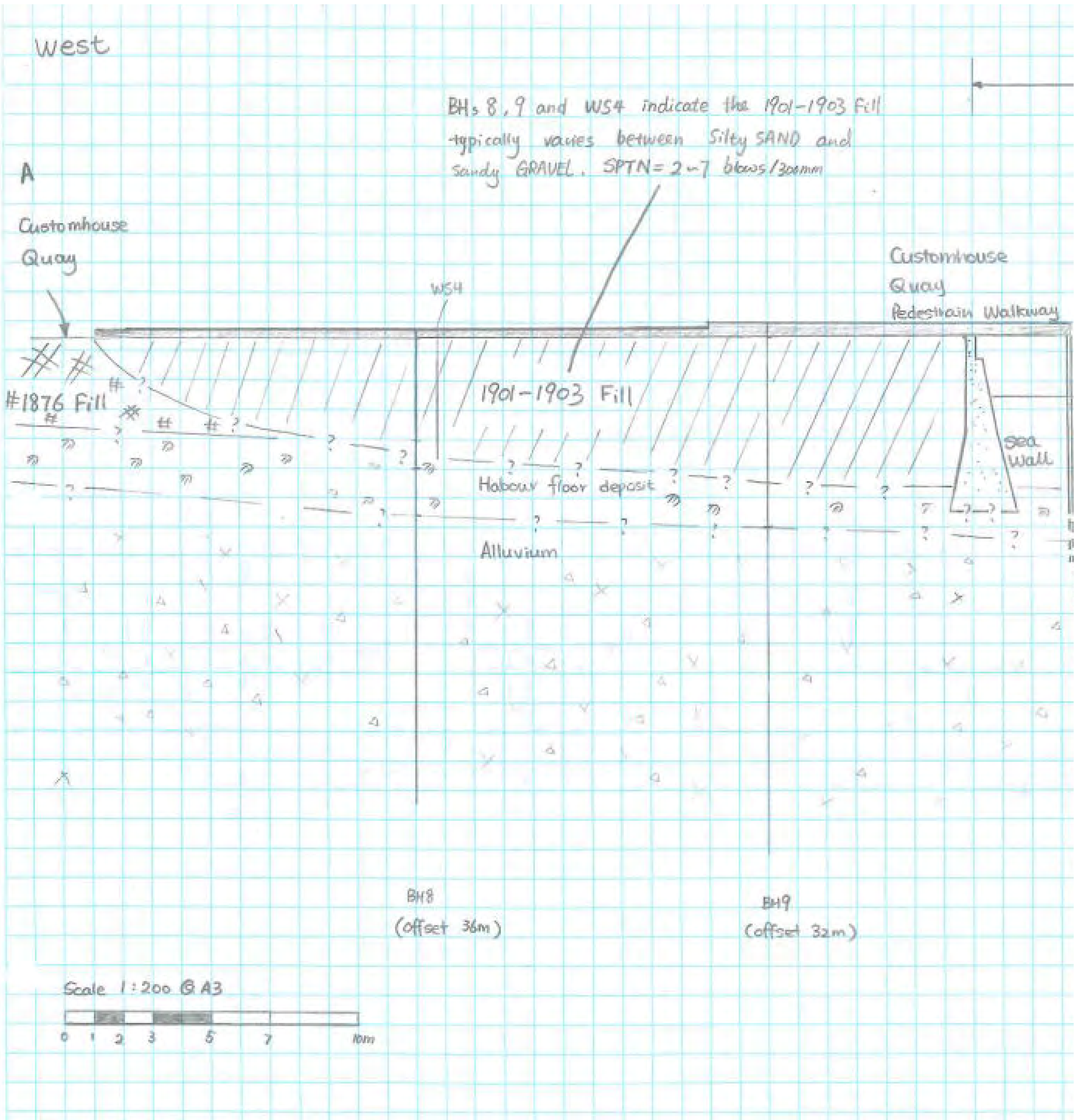
Graeme Quickfall
General Manager

79 Foundry Road, Silverdale 0932
PO Box 225, Silverdale 0944
Phone: +64-9-4263419
Fax: +64-9-4274709
Mobile: +64-21-22 10 100
Email: graeme@hiways.co.nz
Please consider the environment before printing this email

From: Emilia Belczyk [mailto:EBelczyk@tonkin.co.nz]
Sent: Tuesday, 4 February 2014 10:38 a.m.
To: Graeme Quickfall
Subject: RE: Ground improvement for Site 10 at Wellington Waterfront

Graeme,

Please find another version of ground profile below:



Emilia Belczyk
Geotechnical Engineer
Phone: +64 4 381 8560 |Mobile: +64 21 378 276 |DDI: +64 4 806 4986
Website: http://www.tonkin.co.nz/

Tonkin & Taylor Ltd - Environmental & Engineering Consultants
ASB Tower, L3, 2 Hunter Street, Wellington, New Zealand
P.O. Box 2083, Wellington, 6140

From: Graeme Quickfall [mailto:Graeme@hiways.co.nz]
Sent: Monday, 3 February 2014 3:10 p.m.
To: Emilia Belczyk
Cc: Stuart Palmer
Subject: RE: Ground improvement for Site 10 at Wellington Waterfront

Hi Emilia and Stuart

Further to our telephone conversation and the information provided
Could you also please send through an indicative soil profile for the site.

Is the basement excavation depth 3.5 m ?

Regards

Graeme Quickfall
General Manager

Hiway Environmental — POSITIVE ENVIRONMENTAL SOLUTIONS
Hiway GeoTechnical — GEOTECHNICAL SOLUTION PROVIDERS

79 Foundry Road, Silverdale 0932
PO Box 225, Silverdale 0944
Phone: +64-9-4263419
Fax: +64-9-4274709
Mobile: +64-21-22 10 100
Email: graeme@hiways.co.nz

From: Emilia Belczyk [mailto:EBelczyk@tonkin.co.nz]
Sent: Friday, 31 January 2014 4:34 p.m.
To: Graeme Quickfall
Cc: Stuart Palmer
Subject: Ground improvement for Site 10 at Wellington Waterfront

Hi Graeme,

Following our conversation yesterday, please find attached a plan of the ground improvement with one cross section. We have assumed:

- 1m diameter secant wall
- Length 7.5m (Embedment into Alluvium 1m)
- Grid 5.2m except for one section with 6m spacing
- UC steel columns in ever 3rg soil column at the perimeter.

Please provide an estimated cost for this job and an estimated time to completion.

Please feel free to call me on 021 378 276 if you have any questions.

Regards,

Emilia Belczyk
Geotechnical Engineer
Phone: +64 4 381 8560 | Mobile: +64 21 378 276 | DDI: +64 4 806 4986
Website: http://www.tonkin.co.nz/

Tonkin & Taylor Ltd - Environmental & Engineering Consultants
ASB Tower, L3, 2 Hunter Street, Wellington, New Zealand
P.O. Box 2083, Wellington, 6140